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research review

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INFORMATION SCIENCES, 1965

ROWENA SWANSON, Directorate of Information Sciences, AFOSR

The information sciences, as embodied in the program of the Directorate of Information Sciences, AFOSR, and in the programs of several other agencies (e.g., Office of Naval Research and Advanced Research Projects Agency), aim toward the specification of systems of men and machines that optimize the acquisition, processing, and use of information. Products of the information sciences are methods of manipulating and using information and designs for systems and hardware to implement the methods. The information scientes are exploiting, or trying to exploit, not only computers but also all devices or machines that can be used to quantify, store, and transmit information. The information sciences, thus, encompass (or are expected to encompass) not only areas concerned with classifying and storing information, but concerned also with techniques for processing this information and making effective use of it.

The nub of the problem in the information sciences is the definition or meaning of the word, "information." As Oliver Selfridge has said, "Clarification of the concept of information may be the single most important objective for the information sciences in the coming years." Also, "information," as Claude Shannon and others have demonstrated, has its quantitative aspects. Signals of various sorts can be measured and, once a determination has been made as to what is to constitute a signal, methods can be developed for optimizing the transmission and reception of signals embedded in noise. The methods can be very innovative and incorporate routines that automatically adapt, based on input and feedback. When, however, the question is, "What is to be measured?" or "What is the significant bit of information in a given context?"--answers are too frequently qualitative and subjective. It is this realm that must be emphasized in research.

The information sciences draw on knowledge from many of the more traditional sciences to study problems connected with information. Classification systems and indexing methods derive from library science and documentation. How man learns and processes information is an inquiry of the behavioral scientist and the educator. How man and other living systems code and store information is being increasingly examined

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by the neurophysiologist and the molecular biologist in one dimension, and by a newly developing corps of information specialists in another. Mathematicians, logicians, and a newly forming group of programmers are exploring theories and methods of representing information and procedures by which machines can solve problems, and learn, and be creative in ways peculiar to algebraic and symbolic manipulation as well as in ways peculiar to man. The common thread is the relevance of these efforts to the identification and handling of information.

The annual report of the Directorate of Information Sciences, AFOSR, Information Sciences, 1965, (1) summarizes 68 research efforts that constituted the Directorate's program in calendar year 1965. It exemplifies both what the Directorate considered significant for sponsorship in order to provide knowledge for future Air Force systems, and the Directorate's assessment of the range and scope of this new field of science. As stated in the introduction, the program does not include all of the areas of the information sciences, both because of budget limitations and because of overlap with other AFOSR and Air Force laboratory programs. However, the coverage does attempt to highlight fundamental areas where research is needed. These include: information-system organization, classification and indexing methods, methods of transmitting information, methods of representing adaptation and learning, models and measures for language, and systems of logic that could lead to new machine designs and new ways of describing and processing information. The annual report includes a statement of research objectives, a summary of research results,

research review
OFFICE OF AEROSPACE RESEARCH

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JACOB SEIDEN
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and citations to published reports and papers for each effort. A total of 144 publications is reported.

A recent paper in the Air University Review complements the annual report. (2) It considers, briefly, the Air Force investment in computer-based information systems, and discusses several areas of research and exploratory development that are expected to contribute to future military and civilian systems. Ongoing work is reviewed concerning document and data systems, management and command systems, programming languages, and man-machine interaction.

Qualified requesters may obtain both of these documents from the Directorate of Information Sciences, AFOSR, or from the Defense Documentation Center. ★

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new pressure gauge for high vacuums

MICROWAVE PHYSICS LABORATORY
AFCRL

A new type of pressure gauge, based on a technique first applied by Rayleigh and Fraunhofer in the late 1800's for measuring refractive indices of gases, has been developed by Sheldon B. Herskovitz of AFCRL.

The pressure gauge uses as its basic component an inexpensive, commercially available optical interferometer of the Michelson type. It is useful in the pressure range of 10 torr or greater. Portable and extremely rugged, the gauge weighs less than 10 pounds. Its simplicity and relatively low cost give the pressure gauge distinct advantages over other gauges operating in the same pressure ranges.

Essentially, the gauge is comparable to the experimental apparatus used by Rayleigh and Fraunhofer to measure refractive indices. The conventional Michelson interferometer produces a series of rings called interference fringes when one light path length is greater than the other. Such fringes will also be produced if the path lengths are the same; but the index of refraction of the gas in one light path differs from that in the other. To determine the index of refraction of gas, a sample in an appropriate test chamber is placed in one of these optical paths. A characteristic fringe shift occurs for a given index of refraction.

The pressure gauge designed and tested by Herskovitz takes advantage of the principle that the refractive index is directly related to gas density, or pressure. However, to derive pressure values, the temperature and gas composition must be known, together with the fringe shifts associated with gas of a certain temperature and composition.

Herskovitz has calibrated temperature with nine pure gases and several binary gas mixtures. Simple visual observations of fringe shifts permit measurements of atmospheric gas pressures with an accuracy of about one torr over all pressure ranges. More sophisticated read-out using photometric techniques permits greater accuracy; but such read-out has not been attached to the AFCRL system. Because the system has no mechanical or thermal inertia, this optical approach to pressure measurement can respond to instantaneous pressure variations.

The gauge built by Herskovitz consists simply of a conventional optical interferometer, plus a small Pyrex test cell leading from the vacuum system across one of the light paths. Thus only the test cell, constructed entirely of Pyrex, must be added to any vacuum system. Pyrex is used because the residual gases found in all materials may contaminate the gas of interest. To prevent this, the material from which the test cell is constructed must be baked to remove these residual gases. Thus Pyrex, which can resist high baking temperatures, serves as an excellent test-cell material. ★

PHOTOELECTRIC PROCESSES IN YTTRIA

DR. PETER L. LAND, Metallurgy and Ceramics Research Laboratory, ARL

Since many properties of materials are determined by the presence of specific point imperfections (defects), it is desirable to identify these defects and to study their properties so that the knowledge gained can be utilized in the interpretation and eventual control of the properties of the bulk material. Progress toward this end requires the assimilation of various experimental results, such as those of spin resonance, dielectric loss, internal friction, diffusion, conductivity, and polarized luminescence. By co-ordinating such measurements, this laboratory is endeavoring to contribute to a broader understanding of selected metal oxides. Studies of thermoluminescence, thermally stimulated current and fluorescence, which can be carried out with the same basic experimental apparatus, are useful toward this end. The detailed description of the properties of a defect when it alone is responsible for most of the observed photoelectronic processes is illustrated in Fig. 1, which is taken from a recent publication reporting studies of ZnS:Cl single crystals. (1)

The energy levels of electronic states which participate in radiative transitions are determined from the wave lengths of radiation emitted or absorbed. Further characterization of the observed levels and transitions requires measurement of the spacial distribution and polarization of the radiation which depend on the spacial orientation of the defects and their electronic states. The trap energies are deduced from the shape and position of peaks in the thermoluminescence or thermally stimulated current versus

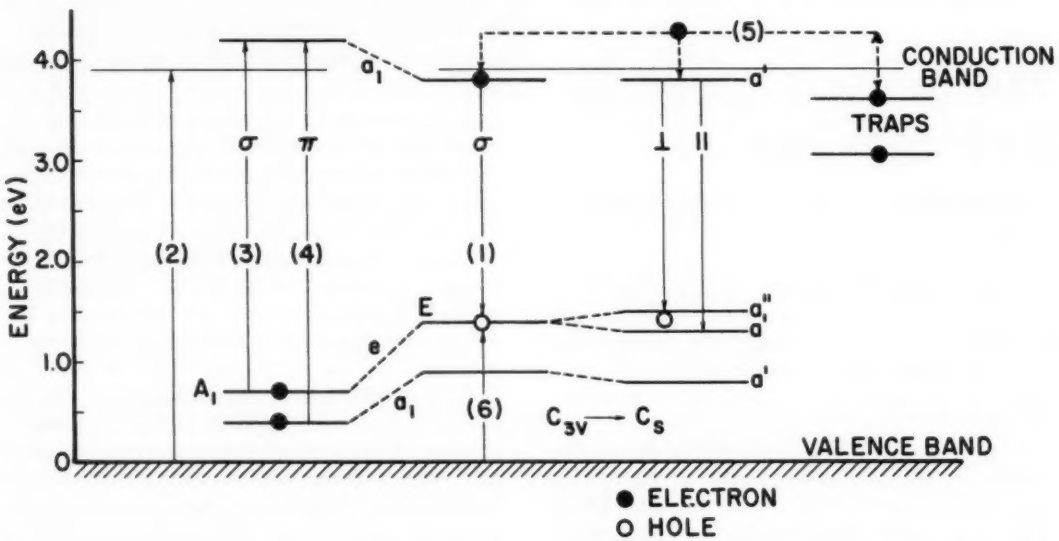

Figure 1. A model of the energy-level scheme for the photoelectronic processes in ZnS:Cl crystal at 77 K. Arrows drawn with solid or broken lines represent optical or thermal transitions of electrons, respectively. The luminescence transitions (1) are caused by the host excitation (2) or by the characteristic excitation (3) or (4). Process (5) represents trapping and thermal ionization of electrons in the trap levels, which is responsible for the thermoluminescence and glow currents. Infrared quenching process is assumed to be the hole transitions (6) from the ionized center into the valence band.

time observed while heating at a known rate.

A detailed study of the photoelectronic behavior of Y_2O_3 has been started. Single crystals are cut into thin sections with faces parallel to crystallographic planes and optically polished. These sections in turn are placed in an optical cryostat, cooled to liquid-nitrogen temperature, and irradiated with ultraviolet light of known intensity, spectral distribution and polarization for a measured time. (This "excitation" causes the occurrence of processes such as 1, 2, 3, 4, and 5, shown in Figure 1.) Upon heating at a constant rate, the total light emission (thermoluminescence resulting from processes 1 and 5) is measured as a function of time. The spectral distribution and polarization of the thermoluminescence are measured by inserting filters and a polarizer between the crystal and detector.

To supplement the information gained from the thermoluminescence measurements, transparent electrodes will be fixed to the crystal sections which will then be treated as above, except that a constant voltage will be applied to the electrodes and thermally stimulated current (glow current), rather than thermoluminescence, will be measured as a function of time. Peaks in the observed current would correspond to electronic transitions from traps to the conduction band (process 5). Absence of a current peak when compared with thermoluminescent peaks would suggest that the undetected trap is a nonradiative state associated with a luminescent center.

The polarization and spectral distribution of fluorescence resulting from exposing crystals to ultraviolet of known spectral distribution and polarization will be measured at selected temperatures (processes 1, 2, 3, and 4).

Quenching effects will be investigated by exposing the crystals to visible and infrared radiation. Thermoluminescence and glow-current peaks may be quenched if the radiation empties traps which were filled by stimulation at an earlier time, while processes such as (6) in the figure may quench thermoluminescence and fluorescence.

Yttria should exhibit polarized luminescence since interstitials, metal vacancies or impurities probably occupy sites in the crystal, each of which has a unique symmetry axis as is required to produce the effects. Even if the measured polarization effects cannot be interpreted from simple dipole models, they should be useful in establishing relations between charge sources such as A_1 and centers such as E.

In accordance with the objectives stated at the beginning, an attempt will be made to correlate data from these experiments with data obtained by other means. The experiments described will be performed on crystals as received, in an oxidized state and in a reduced state, in order to attempt identification of the defects responsible for the high-temperature semiconductive properties of nonstoichiometric Y_2O_3 which were observed by other measurements made in this laboratory. (2) In addition, nonstoichiometric and doped crystals will be subjected to combined thermoluminescence-spin resonance studies being conducted at the Franklin Institute under an Air Force contract. (3)

The continued study of yttria is considered to be of practical interest to the Air Force because it is representative of a class of materials which have potential use as lasers (4) and as efficient phosphors. (5) Yttria may also be of use in the future as an inert infrared window material; it is already an important structural material for nuclear reactions. (7) Furthermore, as a result of the increased interest in yttria, the growth of larger and higher-purity crystals for continued study can be anticipated. (8) ★

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BOUNDARY LAYERS IN PLASMA ACCELERATORS AND GENERATORS

DR. DEMETRIOS G. SAMARAS, Directorate of Engineering Sciences, AFOSR

Certain general laws are valid for all branches of fluid dynamics, including aerodynamics and plasma (ion flow) dynamics; others are valid only for a specific branch. To extend the validity of a law from one branch to another, drastic changes in the law are sometimes needed. For example, the concept of the "boundary layer," a fictitious, discrete transition region first applied in aerodynamics, has been extended to plasmadynamics, though not without considerable modification.

The boundary layer, so named by Ludwig Prandtl, is the transition region between the surface of a solid and the main flow around the solid; it has the important characteristic wherein the forces of interaction between fluid and solid are transmitted through it.

In aerodynamics, the boundary layer relates to the viscosity of the fluid. Thus its structure depends both upon the geometry and the Reynolds number.

In plasmadynamics, the boundary layer relates to more dissipation phenomena than is the case in aerodynamics. These phenomena include viscosity, electrical and thermal conductivity, and the diffusion of various particles. It should be emphasized that, in most cases, the flow consists of a mixture of three or more component fluids, such as electrons, ions, and neutral species. In addition, the solid walls carry electric currents and produce sheaths in the flow with more-or-less steep voltage gradients.

As early as 1929, Irving Langmuir discovered that a plasma flow does not approach the wall unaltered but forms space charge regions. Subsequently, it was established that a unipolar layer forms close to the wall, and that a transition layer appears between it and the main plasma flow. This generation of space charge layers may be attributed to the fact that one of the charged-species components diffuses faster than the other.

The initial objective of contract AF 49(638)758, under the guidance of Professor Frank Marble of the California Institute of Technology, was to investigate certain aspects of boundary layers between plasmas and electrodes as well as between plasmas and side walls. These boundary layers appear in direct-current machines, such as plasma accelerators and electrical-power generators.

Professor Marble's early experiments indicated that the assumption of a single fluid having a local equilibrium temperature could not account for the lower heat transfer and higher electrical conductivity observed. Consequently, a mixture of two or three component fluids was necessary to account for the observed heat transfer and conductivity. In this model, the temperature of the electrons was considerably higher than that of the ions or neutral atoms.

As the presence of electricity considerably modified the boundary layer, the voltage current characteristics were measured. These experiments showed that two different modes of operation exist for a steady-state current conduction between high-temperature electrodes in a potassium-seeded argon plasma. In both modes of operation, the electron emission from the cathode was caused by thermionic emission. With tungsten electrodes at an average temperature of 1700°K, the steady-state current densities measured were over 2 megamp/m^2.

In the first or normal mode of operation, the current density measured was smaller than that corresponding to the thermionic emission limit. However, in the second or current-limited mode it was equal to the limit. Again, in the first mode, the cathode sheath potentials were on the order of a few $k_B T_W$ (where k_B = Boltzmann's constant and T_W = wall temperature), whereas in the second mode they were considerably larger.

Dr. Marble's achievement brings us a step closer to the attainment of nuclear space propulsion. ★

exploring optics theory with microwaves

MICROWAVE PHYSICS LABORATORY
AFCRL

A classic experiment in optics is the "two-pinhole" experiment first performed around the beginning of the 19th century. This experiment demonstrated the wave nature of light. In the experiment, light passes through two pinholes placed side by side, and is projected onto a screen. Where the light diffracted from each of the two pinholes overlaps, a series of interference fringes or bands appears on the screen. The contrast between the light and dark bands is closely related to the coherence of the light. Thus, interference is simply another way of looking at coherence.

AFCRL scientists J. L. Poirier, W. Rotman and R. A. Shore have repeated the classic pinhole experiment--but at microwave frequencies. The AFCRL experiment is an important bench mark in the new and rapidly growing field of microwave optics. This hybrid field combines and, in many instances, makes interchangeable microwave and optical theories.

Superficially related experiments with microwaves have been carried out for many years. But in all cases, the microwave radiation was coherent. The AFCRL group is the first to use an extended source of incoherent microwave radiation. Only when the source is incoherent do we have a macroscale replication of the optical situation. And only with such an incoherent source of microwave radiation is it possible to demonstrate experimentally the validity of applying the well-developed body of optical-diffraction theory to microwaves--and to examine experimentally certain aspects of diffraction theory itself.

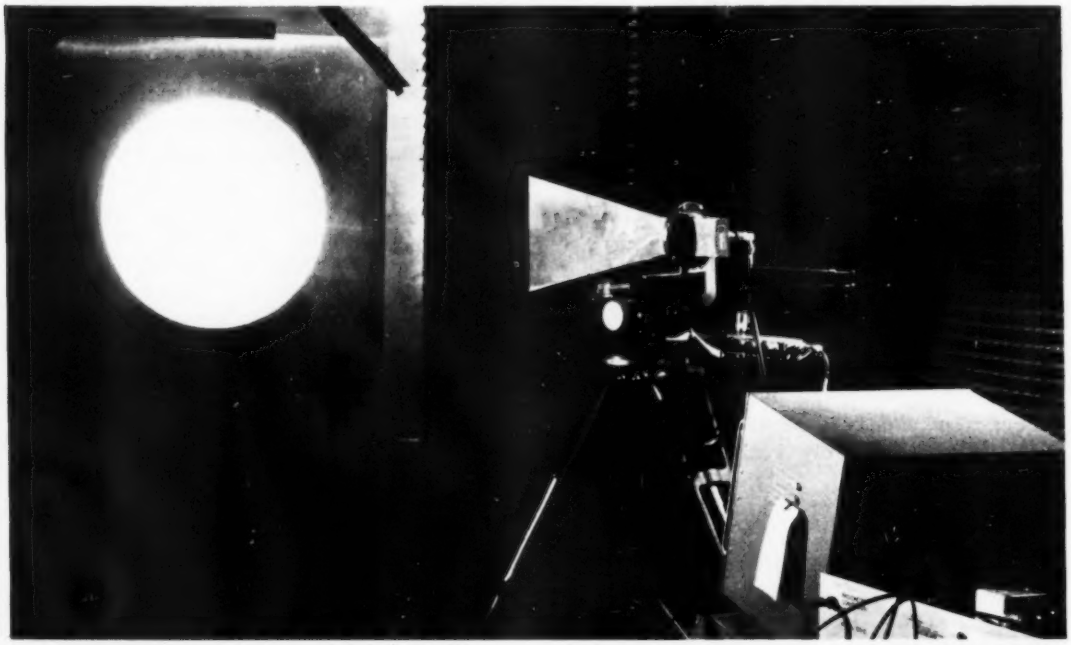
One area of interest is to extend diffraction theory developed from cases in which apertures are much larger than the wave length of the diffracted radiation to cases in which the apertures are of the same order of magnitude as the wave length. The problem that arises in optical experiments is simply that optical wave lengths are so short that the apertures (pinholes) in the experimental apparatus must be correspondingly microscopically small--much too small to be easily fabricated. But when the experiments are conducted at microwave frequencies, the wave lengths are long enough so that the apertures can range in size from six inches to a foot or so, and a variety of aperture geometries of precisely known dimensions can be used.

The experimental apparatus used by the three AFCRL scientists to conduct the microwave studies does not differ in essence from that used in the optical pinhole experiments. There is an emitter of incoherent radiation and, depending on the particular study, a shield containing one or two apertures at some distance from the source. Instead of a screen, two moveable microwave horns are used. Signals from these horns are combined and fed into amplifying and filtering devices. By moving the horns farther apart or closer together, the experimenters are able to map the interference fringes as a function of the horn spacing. The intensity variations are a measure of the degree of coherence. Apertures of differing sizes and geometries can be used to obtain radiation of any desired coherence. Close agreement was found between the experimental results and what had been predicted by optical theory.

The key to the experiment, however, was finding an extended source of incoherent radiation at microwave frequencies. Such a source exists in standard fluorescent tubes--but until the AFCRL experiment, no one had any thought of applying this source to the study of microwave diffraction. The source, in the AFCRL experiment, consisted of a 1.22-meter-square array of fluorescent lights. (The light emitted is of no interest to the experimenters.) Before the Poirier, Rotman and Shore experiment, the only way to obtain incoherent microwave radiation from an extended source was to heat a metal plate. However, the radiation from such a source is not much greater than the thermal background noise.

This research is of interest to the Air Force because of the new insight it provides into the behavior of antenna systems. This

insight could in turn result in improved designs for use in such areas as radio astronomy, airborne reconnaissance radar, over-the-horizon scatter communications and, in short, any microwave system that involves the properties of partially coherent fields.



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In photo #1, one of the two horns used to detect microwave radiation is shown facing an aperture placed before an array of fluorescent lights (photo #2).

model for scintillation

DR. JULES AARONS
Space Physics Laboratory, AFCRL

Stars scintillate (that is, they twinkle), but planets do not. Radio signals from satellites and from radio stars also scintillate, but some radio sources scintillate more than others. Why?

Scientists from the AFCRL Radio Astronomy Branch, using the 1000-foot radio telescope at Arecibo, Puerto Rico, have shown that scintillation of both optical and radio sources is primarily a function of the angular diameter of the source. By angular diameter is meant the apparent size--or, more precisely, the angle of two lines extending from either side of the source and converging at the point of observation.

The AFCRL study shows that the smaller the angular diameter of the source, the greater the scintillation. Thus, stars with small angular diameters twinkle; planets with larger angular diameters do not. The study also indicates that the rate of scintillation does not in general vary with frequency. Eight signal sources above the atmosphere were studied. Angular diameters ranged from less than one second of arc to 29 minutes of arc. Observations were made with radiometers operating in the 22.3 to 38.75-Mcps range.

There would, of course, be no scintillation regardless of the angular diameter of the source if the signal did not pass through the uneven and irregular layers of the ionosphere. It is possible, therefore, to learn something of the dimensions of ionospheric irregularities by analyzing scintillations--and, in fact, many researchers have done just that. Usually this has involved a number of receivers spaced over a large area on the ground. Because scintillation itself is nothing more than variations in the amplitude of the received signal, it is possible to compare the signals received at these spaced receivers and to derive information on ionospheric irregularities.

The AFCRL study shows that it is possible to derive information on the dimensions of ionospheric irregularities by using a single receiver if the angular diameter of the source is known.

In passing, it might be noted that different investigators have estimated the mean size of ionospheric irregularities as ranging from about 0.5 km to 7.5 km or greater. The size varies with latitude, season, time of day, solar cycle, and even with the direction in which the observer is looking. The AFCRL measurements showed the irregularity size to average about 1.1 km.

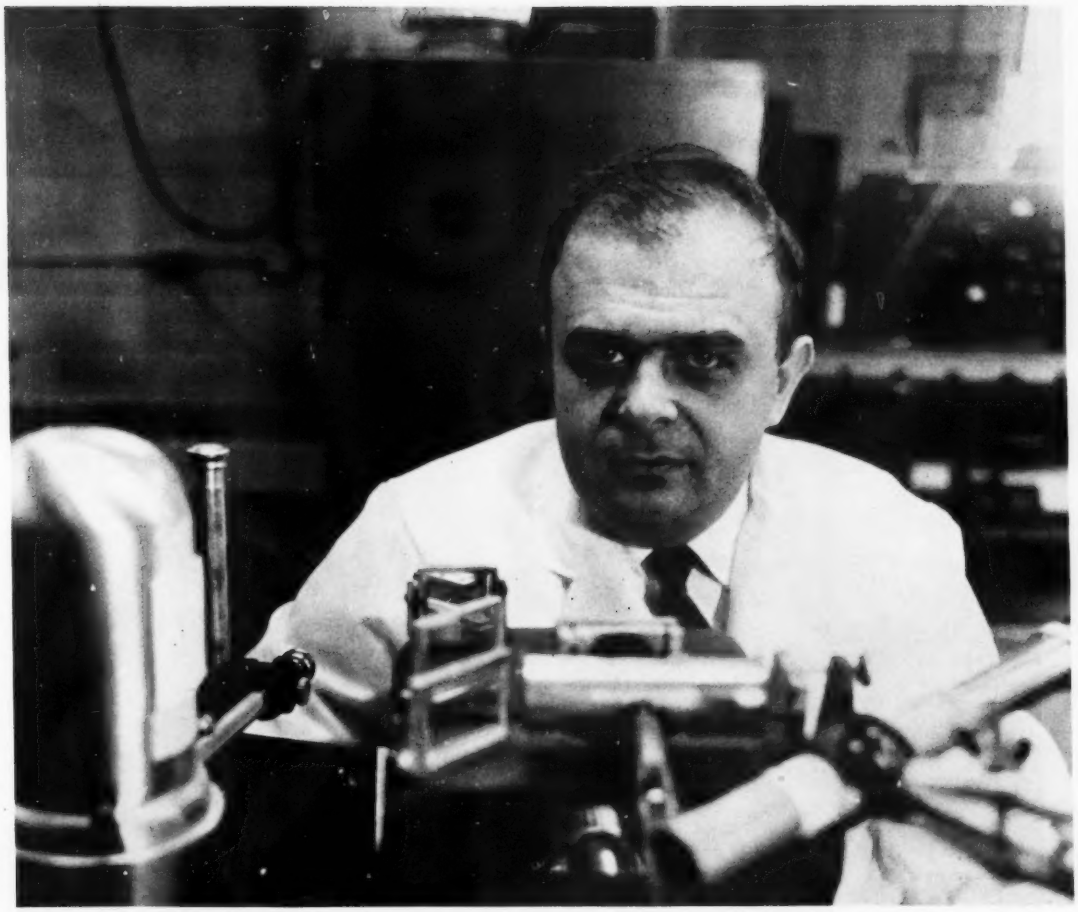
Why sources with small angular diameters scintillate, while those with large angular diameters do not, can be explained equally well by diffraction theory and by scattering concepts. Using diffraction theory, we can consider a small-angular-diameter source as consisting of one or a limited number of pinholes through which electromagnetic energy passes. Phase interference produces a series of interference fringes on the ground. If the ionosphere were stable and uniform, no scintillation would be observed. But because it is not stable and uniform, the energy passes through a medium whose index of refraction is continuously varying, thus causing a continuous oscillation in the diffraction pattern. This produces the amplitude variations that we know as scintillation. A large extended source, on the other hand, can be considered as consisting of many point sources of radiation. The addition of shadows from each of these many discrete points averages out the amplitude variations, thereby cancelling scintillation.

However, scattering concepts can explain the phenomena equally well--and scattering concepts are in fact more useful in determining ionospheric irregularities. Under scattering concepts we can imagine the opposite edges of an extended source as vertices of scattered cones of radiation. The correlation of the scintillation pattern from extreme parts of the source will diminish if the phase-path difference between the length of the generator of one cone and that included by the other measured along the same path length exceeds one radian. ★

PROFILES

Dr. Edward E. Altshuler, Microwave Physics Laboratory, AFCRL, whose work was described in the article, "Earth-Space Millimeter-Wave Communications" in the May 1966 issue of the Review, is presently supervising research programs to determine the effects of the lower atmosphere on millimeter-wave propagation for potential applications in the areas of earth-to-space and re-entry communications and high-resolution radar systems. Dr. Altshuler received the B.S. in Physics from Northeastern University (1953), the M.S. in Physics from Tufts University, Medford, Mass. (1954), and the Ph.D. in Applied Physics from Harvard University, Cambridge, Mass. (1960). After graduation from Harvard, he engaged in research on antenna arrays and spherical antennas as an electronics scientist in the Radiation and Reflection Branch, Electromagnetic Radiation Laboratory, AFCRL. From 1961 to 1963, he was manager of research and development with Gabriel Electronics, Millis, Mass. Since 1963, he has been Chief, Transmission Branch at AFCRL's Microwave Physics Laboratory.

Mr. James C. Sethares, a research physicist with the Microwave Physics Laboratory, AFCRL, is investigating magnon-phonon interactions in ferrimagnetic single crystals. His interest in this area began in 1962 when he came to AFCRL. He has a B.S. in Electrical Engineering from the University of Massachusetts (1959), and an S.M. in Electrical Engineering from the Massachusetts Institute of Technology (1962). He has written a number of publications and is a member of the Institute of Electrical and Electronic Engineers. One of his current interests was described in the May 1966 issue of Review in the article, "Phonons, Magnons and Coupled Transmission Lines."



Mr. Sheldon B. Herskovitz, a supervisory research physicist with the Plasma Electromagnetics Branch, Microwave Physics Laboratory, AFCRL, is currently directing research dealing with the interaction of matter and energy with ionized gases. Of major interest is the production of plasmas and the determination of the properties of ionized media. Mr. Herskovitz received the B.S. in Chemistry from M.I.T. (1951), and the M.A. in Chemistry from Harvard University (1955). He served as an officer in the Air Force from 1951 to 1953. After separation from the Air Force, he was employed as a research and development engineer with Microwave Associates, and later joined the Radar Laboratory of AFCRC (now AFCRL). Mr. Herskovitz is a member of the Institute of Radio Engineers, the American Physical Society, the Association of Harvard Chemists, and the Scientific Research Society of America. An article on Mr. Herskovitz's "New Pressure Gauge for High Vacuums" appears in this issue of the Review.

Dr. Peter L. Land, a research physicist with the Metallurgy and Ceramics Research Laboratory, ARL, is the author of the article, "Photoelectric Processes in Yttria," which appears in this issue of the Review. His current research is part of a program for understanding and controlling the influence of defects on electrical, mechanical, and optical properties of single-crystal and polycrystalline nonmetallic materials. Dr. Land received his B.S. (1958), M.S. (1960), and Ph.D. (1964) from the University of Missouri. From 1951 to 1955 he served in the Navy as an aviation electronics technician. In the summer of 1960 he worked as a physicist in the Metallurgy and Ceramics Research Branch at ARL. During the summers of 1961 and 1962, he was employed in the Solid State Physics Division of Brookhaven National Laboratory. He has been in his present position at ARL since October 1964.

Dr. H. Stuart Muench, research physicist with the Upper Atmosphere Branch, Meteorology Laboratory, AFCRL, is presently studying the circulation of the stratosphere. In particular, he is interested in the effects of tropospheric disturbances on stratospheric circulation, and the effects of solar heating and infrared cooling. Dr. Muench received his B.S. (1952) and M.S. (1956) in Meteorology from M.I.T. From 1961 to 1963, he studied and taught meteorology at the University of Washington, Seattle, Washington, receiving the Ph.D. in Atmospheric Science from that institution in 1964. While an Air Force weather officer assigned to Bolling Air Force Base, Washington, D.C., from 1952 to 1954, Dr. Muench served for several months at the Analysis Center of the Weather Bureau. He is a member of the American Association for the Advancement of Science and of the American Meteorological Society. An article on Dr. Muench's work, "Explosive Warming in the Stratosphere," appeared in the May 1966 issue of the Review.

Dr. Robert E. Riecker, Wave Propagation Branch, Terrestrial Sciences Laboratory, AFCRL, is engaged in a program to determine the physical and mechanical properties of rocks and minerals, under geophysically realistic conditions of high temperature and pressure, in order to learn more about the phenomenology of earthquake sources and to develop data useful for distinguishing between natural earthquakes and underground nuclear explosions, as part of the Advanced Projects Research Agency's VELA-UNIFORM Project. Dr. Riecker received the B.A. cum laude in Geology (1958), and the Ph.D. in Geology (1961) from the University of Colorado, Boulder, Colorado. He holds membership in the American Association of Petroleum Geologists, Phi Beta Kappa, Sigma Xi and other organizations. An article describing his work, "Earthquake-Triggering Mechanisms," appeared in the April 1966 OAR Research Review.

Mr. James F. Morrissey, Chief of the Direct Sensing Techniques Branch, Aerospace Instrumentation Laboratory, AFCRL, is concerned with the development of meteorological sensors for balloon, rocket, and aircraft use. These include types sensitive to temperature, pressure, humidity, density, and index of refraction. An article concerning Mr. Morrissey's work on a system for measuring wind speed and direction at various altitudes appeared in the April 1966 issue of the Review under the title, "Method for Measuring Vertical Wind Profile from Aircraft." Mr. Morrissey received his B.S. degree from the University of Massachusetts in 1956. From 1956 to 1960, he was associated with the Crosley Research Laboratory, Boston, Mass., and from 1960 to 1961 with AVCO Corporation in Wilmington, Mass. As a systems design engineer with AVCO, he was concerned with the design of electronic and electromechanical instrumentation and systems integration for the Titan and Minute Man missiles. He joined AFCRL at the end of 1961.

Anomalies in Electron-Density Probes Can Be Caused by Rocket Outgassing

UPPER ATMOSPHERE PHYSICS LABORATORY, AFCRL

Contamination of the ionosphere by rocket outgassing--the leakage and diffusion of left-over fuel after burnout--can be a major source of error for electron-density probes according to J. C. Ulwick and Dr. W. Pfister of AFCRL. In a recent article in Radio Science, they show how rocket outgassing explains some puzzling anomalies that have appeared in ionospheric sounding data ever since the early V-2 flights when rockets were first used extensively to probe the upper atmosphere.

These anomalies generally showed up as discrepancies between the electron density measured at a given altitude on the upward portion of a probe's trajectory, and that measured at the same altitude during the downward leg. In early experiments, in which the delay times of radio pulses transmitted from the rocket were used to measure electron density, delay times on the upward leg would be smaller, indicating a reduced electron density. When this effect was first observed, it was interpreted as evidence that the ionosphere's E layer was actually two layers, with a sharp minimum in electron density between them. Later, this effect was reinterpreted as having been produced by local irregularities in the ionosphere; but the man-made nature of these irregularities was not recognized until rockets were instrumented with probes for measuring ambient electron and ion densities directly.

When such probes were flown, the surprising result was that the data telemetered back indicated a local deficiency of electrons, while the positive ion count remained unaffected. In addition, the electron count on the downward portion of the trajectory was less than that on the upward leg, though both were less than electron densities obtained from ionosonde measurements. In 1961, Ulwick and Pfister first recognized the likelihood that these effects were the result of rocket outgassing. Since that time, they have developed a theory to account in detail for the outgassing effect, and have instrumented a number of probes to test their theory and to determine which rocket-vehicle types are most susceptible to outgassing.

In the Aerobee-150 rockets which Ulwick and Pfister used extensively in their ionospheric studies, the oxidizer (nitric acid) is used up before the fuel (a mixture of aniline and furfural alcohol). Outgassing occurs when the residual fuel escapes through the valves which are left open after burnout. As the liquid fuel passes into the near-vacuum of the ionosphere, it is vaporized and diffuses around the vehicle. The free electrons in the ionosphere become attached to the molecules of vaporized fuel, while the positive ions remain unaffected. This accounts for the local reductions in electron densities that are observed.

Since this "hole" is somewhat directional--that is, it becomes more pronounced toward the rear of the rocket--the measured effects are different on the upward and downward parts of the trajectory. Outgassing effects occur primarily above 100 km. At lower altitudes, the surrounding air is dense enough so that the outgassed fuel is swept completely behind the rocket.

Once the effect of fuel outgassing was discovered, it was fairly easy to correct in the case of the Aerobee 150. A valve that simply shuts off the flow of fuel after burnout was activated. And, in fact, this solution is applicable to any liquid-fuel sounding rocket. But what about solids? Residual vapors may or may not be left inside the combustion chamber after burnout, depending on the type of motor; but stopping solid motor outgassing when it does occur may prove a more difficult problem than with liquids.

Outgassing--leakage and diffusion of fuel remaining after burnout--in rockets such as this Aerobee 150 has been found by AFCRL scientists to contaminate the ionosphere and to be a major source of error in electron-density probes.

Ulwick and Pfister are currently studying data from solid-fuel sounding rocket flights to determine which vehicles show outgassing. So far, they have found it occurs with the Astrobee 200, a solid-fuel rocket similar to the Aerobee 150 in performance, and the Black Brant, a single-stage rocket used to loft heavy pay loads to moderate altitudes. Fortunately, the 4-stage (all-solid) Blue Scout rocket, which is used extensively for measuring charged particles in the radiation belts, showed no indication of outgassing. Data from flights of a number of other solid-fuel sounding rocket types (particularly the Nike-boosted series) have not provided conclusive evidence one way or the other. ★

HIGH-ENERGY X RAYS FROM THE CRAB NEBULA

DR. ERICH WEIGOLD, Directorate of Physical Sciences, AFOSR

A supernova is a star which explodes catastrophically with a sudden release of a large fraction of its energy. It is brighter than any but the largest galaxies. Unfortunately, supernovae are rather rare and are, therefore, difficult to study. In historical time, the only supernovae observed in our Galaxy occurred in 1054, 1572 and 1604. The remnants of the supernova of 1054 are still visible as an irregular expanding nebula known as the Crab Nebula, consisting of matter propelled outwards from the star by the explosion.

There appear to be two types of supernovae. Type I, such as the Crab, is brighter and has larger explosive velocities than Type II. In 1957 Burbidge, Burbidge, Fowler and Hoyle (1) developed the idea (2) that the roughly exponential decrease in the light output observed after the first 100 days following a Type I supernova is due to the energy released by the spontaneous fission of Cf^{254}. The half life for that process is about 55 days, in rough agreement with the observed half life for the early luminosity of a Type I supernova. In some more recent

papers Hoyle and Fowler elaborated on this theme and made some modifications to the theory. More recently, however, Hoyle, Fowler, Burbidge, and Burbidge (3) proposed an alternative explanation for Type I supernovae, which is based on gravitation rather than nuclear energy. With the theory in such an unsettled state, it is up to experiment to decide, if possible, which of the two alternative sources of energy in supernovae is more nearly correct.

With this in mind, Professors D. D. Clayton, R. C. Haymes and W. L. Craddock (4) of Rice University calculated the nuclear gamma-ray spectrum to be expected from supernova remnants if the Cf^{254} hypothesis is correct. These calculations, supported by the Nuclear Physics Division, AFOSR, demonstrated that a detectable amount of radioactivity should be present in supernova remnants such as the Crab Nebula, and suggested that an experimental test of the californium hypothesis may be made by searching for the gamma-ray lines associated with the anticipated trans-bismuth radioactivity. Although the calculated gamma-ray line spectrum is complex, almost all of the radiation should be in the energy range 50 KeV to 400 KeV, and photons of these energies can penetrate to balloon altitudes without serious attenuation. Professor Haymes, with support provided by the Nuclear Physics Division, AFOSR, designed an experiment to search for these lines. Background considerations made it obvious that a gamma-ray telescope of small solid angle and very good energy resolution would be required. Furthermore, the telescope must completely reject other forms of radiation, such as charged particles.

On October 19, 1965, Dr. Haymes launched a balloon at Palestine, Texas. The 800-pound pay load contained a carefully designed gamma-ray telescope which fulfilled the necessary requirements of sensitivity, energy resolution, and angular resolution.

Although the analysis for possible gamma-ray lines has not been completed, a relatively large flux of X radiation with photon energies up to 80 KeV was observed. The analysis of this X-ray spectrum was presented at a recent meeting of the American Astronomical Society held at Langley, Virginia. A fuller account is to be published in the Journal of Geophysical Research. Haymes and Craddock find that the X-ray flux at the top of the atmosphere can best be approximated by a single exponential over the entire energy range. The expression for the flux is 1.1 exp (-.119E) photons Cm^{-2} Sec^{-1} KeV^{-1}, where E is expressed in KeV.

As a rule, it is assumed that the X rays emitted by stellar objects are produced either by the synchrotron mechanism, or as a result of bremsstrahlung from a hot gas. The synchrotron mechanism is based on the idea that relativistic electrons moving through a magnetic-field region are deflected from linear motion and, therefore, are accelerated. Since accelerated charged particles emit radiation, these electrons emit radiation which is known as synchrotron radiation. The higher the energy of the electrons and the higher the magnetic field, the higher the energy of the emitted photons. In the case of the Crab, in order to provide the high-energy X rays observed in the experiment, the synchrotron source would require an active source of extremely high-energy (approximately 10^{14} eV) electrons if one assumes the reasonable values of 10^{-4} gauss for the magnetic field. It is difficult to see how an active source of such high-energy electrons can exist in the Crab. Furthermore, the synchrotron mechanism would produce a power-law energy spectrum in disagreement with the observed exponential spectrum.

Bremsstrahlung (braking radiation) is the radiation emitted by a charged particle when it is decelerated on passing through an absorber. The bremsstrahlung spectrum expected from a hot gas is exponential, in agreement with the observed X-ray energy spectrum. The temperature of the hot gas can be deduced from the shape of the energy spectrum, and the result for the Crab is 10^8 degrees Kelvin.

Haymes and Craddock also postulate a mechanism for generating such high temperatures. The expansion velocity of the Crab Nebula is observed to be approximately 1100 km/sec. A plasma streaming at this

velocity will encounter shock waves wherever there are obstacles to the plasma flow (such as the interstellar medium and the filaments in the Crab). In the earth's magnetosphere, for instance, where the solar-wind velocity is approximately 400 km/sec, the shock results in temperatures (5) of 10^7 degrees Kelvin.

This balloon flight is the first of a series to be undertaken by the Rice University group. Future flights, at somewhat higher altitudes, will be undertaken to study the gamma-ray spectrum from the Crab in more detail as well as to observe other interesting stellar objects in the high-energy X-ray and nuclear gamma-ray region. ★

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Balloon Drop Tests of Surveyor Vehicle

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

When NASA's Surveyor lunar vehicle lands on the moon in 1967, its rocket-cushioned descent will have been well rehearsed. Extensive balloon-borne drop tests of the vehicle have been made by AFCRL scientists to perfect the soft-landing technique.

More than 70 tethered balloon ascensions to an altitude of 1,500 feet for vehicle drop tests have been conducted by AFCRL at its permanent field site at Holloman AFB, New Mexico, over the past 3 years to test the Surveyor spacecraft's retrofire descent and impact capabilities. Surveyor is supposed to land on the moon with no more of a jolt than a parachutist feels on hitting the earth.

The balloon platform constitutes a stable drop tower without the impediments of a tower structure itself. The test bed also approximates a moon environment in that it satisfies the need for a short drop with insufficient time for atmospheric drag to build up around the lunar lander. The precise positioning of the balloon at a fixed altitude also provides maximum visual coverage and a reasonable measure of safety for participating personnel. The tethered balloons used in the tests are 66 feet in diameter.

To achieve the stable platform and to allow the Surveyor vehicle to be dropped free of any possible entanglement with tethering lines and to impact within 50 feet of ground zero, 3 winch-equipped trucks are employed. The tether lines form a triangle and are secured to the bottom-end fitting of the balloon. The Surveyor vehicle is suspended beneath an open parachute which is also tied to the same bottom-end fitting.

After the Surveyor vehicle is preflight tested, the balloon and its payload are ready for release and reel-up. Following inflation and release from roller arms, the balloon is restrained through the use of an explosive-type release device at the end of a crane boom. When the release is fired, the balloon rises to about 100 feet and then is restrained by the 3 tether lines. At the command of the field-test director, winch operators begin the reel-up. As this is being done, a precise positioning technique is used to place the system over ground zero. With the balloon and lander at 1,500 feet, the operation is turned over to the NASA Surveyor project manager.

With all of the lander's systems operating, the vehicle is dropped. At 800 feet, vernier rockets begin firing. They cut out at 500 feet. From that height, the parachute recovery system brings the vehicle to the ground at a rate not exceeding 20 feet per second on inflated air bags fitted to the legs of the lander. Following the completion of a drop test, the area is cleared and the balloon lowered for a repeat performance. ★

Airborne Geological Survey in The Middle East

TERRESTRIAL SCIENCES LABORATORY, AFCRL

An airborne geological survey over several Mediterranean and Middle Eastern countries to collect data on dry lake beds for natural landing areas has been undertaken by AFCRL scientists. They are also investigating the geology of river valleys and volcanic geothermal areas. The month-long survey got under way this past May, using instrumentation aboard a C-130 aircraft.

The key instrument aboard the aircraft is a nine-lens camera system for taking simultaneous photographs at nine different narrow-band regions of the visible and near-infrared spectrum. By studying the tonal contrasts of the photographs, characteristics of the terrain can be determined. In addition to the nine-lens camera, a thermal infrared optical-mechanical scanner and a conventional aerial camera is being used.

The survey is being made over Libya, Iran and Jordan. As an adjunct to the survey, AFCRL, at the request of the Italian Government and Dr. Froelich Rainey of the University of Pennsylvania Museum, is using the instrumented aircraft to examine the Plain of Sybaris on the southern coast of Italy in an attempt to locate the lost city of Sybaris, the richest of the pre-Golden Age Greek cities.

Another feature of the survey is an attempt to locate geothermal areas which can serve as natural-energy sources for steam electric-power generators. Such generators have been in use in Italy for a number of years. The thermal infrared scanner is being used for this survey which is being made in the Larderello area. The area around Mt. Vesuvius is also being mapped.

Although the search for Sybaris began as early as 1878, it was not until 1960 that an all-out effort was made to find the city. This city of 300,000 was the wealthiest settlement in the Greek world some 2,500 years ago. Archeologists generally agree that they have located the Port of Sybaris; but the city proper lies beneath nearly 30 feet of sandy soil, and its exact location and boundaries are unknown. Excavation is difficult because the buried site is below the water table.

It is hoped that the AFCRL survey using the nine-lens camera and the thermal infrared system will help delineate the boundaries and other features of the lost city.

The main object of the survey is the location of large, dry, flat areas with soil sufficiently compact to support aircraft. During the past four years, AFCRL has made extensive studies of dry lake beds in the western United States, and has identified and catalogued scores of such natural landing areas suitable for emergency operations. The airborne survey will help identify such areas in the Middle East.

The nine-lens camera was developed by the Itek Corporation, Lexington, Mass., and the IR scanner by Michigan University, both under the direction of Carlton E. Molineux of AFCRL. 1st Lt. Richard S. Williams, Jr., is the project officer for the aerial survey. ★

AFCRL Satellite Measures Charged-Particle Distributions out to 3,090 NM

SPACE PHYSICS AND UPPER ATMOSPHERE PHYSICS LABS AFCRL

An AFCRL satellite, instrumented to measure the angular distribution and energies of charged particles in the earth's magnetic field and upper ionosphere, was launched from Vandenberg AFB, Calif., 22 April 1966. The OV3-1 (OV for orbiting vehicle) satellite was boosted into a polar orbit by a Blue Scout rocket with an apogee of 3,090 nautical miles, a perigee of 192 nautical miles, a period of 151 minutes, and an orbital inclination of about 80 degrees.

The specific objective of the launch was to determine the distribution of energetic charged particles (electrons and protons) in the earth's magnetic field. AFCRL scientists are primarily interested in the pitch angle

of the particles (angle of the particles with respect to the magnetic field).

The satellite carried a spherical electrostatic analyzer for measuring low-energy ionospheric charged particles, and two curved-plate electrostatic analyzers for measuring high-energy radiation belt electrons and protons up to about 100 Kev. Two other instruments, an electron spectrometer and a proton spectrometer, were aboard to obtain the energy spectra of particles up to an energy of a few Mev. Also, a Geiger counter was used to measure the radiation counts in order to compare radiation-intensity data with that obtained in previous AFCRL satellite measurements made between 1960 and 1963.

All of the instrumentation was directional except for the spherical electrostatic analyzer and the Geiger counter, which were omnidirectional. Two sets of standard aspect magnetometers were also on the satellite for determining the orientation of the directional instruments with respect to the magnetic field.

AFCRL scientists Don F. Smart and Rita C. Sagalyn are in charge of the project. ★

nonlaser optical radar

OPTICAL PHYSICS LABORATORY, AFCRL

A short-range, nonlaser optical radar system, having a number of advantages over laser devices, has been demonstrated by Dr. Heinz Fischer of AFCRL. This system, which uses a small but extremely intense arc-lamp called the Nanolite, has been successfully tested on targets 100 feet away. Dr. Fischer believes a more sophisticated version will be able to detect and range objects as far away as 1500 feet, with an accuracy of a few inches.

Basically, Dr. Fischer's system consists of the Nanolite, a collimating lens, a photoelectric detector, and an electronic timing device. A pulse of light sent through the lens is detected as it leaves the device, and then again after it returns on reflection from the target. The travel time of the pulse is then converted into range. This is, of course, the basic principle of all radar systems.

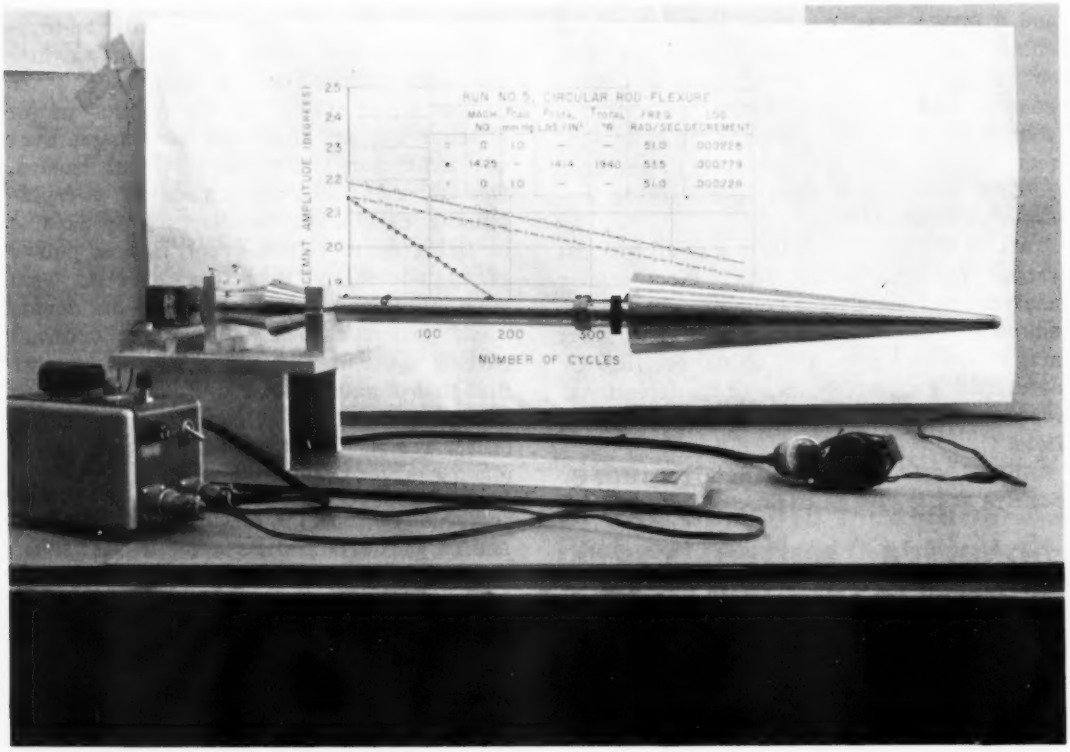
However, Dr. Fischer's system offers a number of advantages over both conventional and laser radars for short-range applications. The advantages over conventional radars are resolution of small objects and more accurate ranging. Other advantages are its small size, low power requirements, low cost and ruggedness--advantages which it also has over laser systems. The Fischer system requires only a small, battery-operated power supply. A system weighing just a few pounds could be built.

The operating characteristics of the Fischer system also offer advantages over the laser for short-range optical radars. One of these characteristics is a rapid-pulsing capability. The Nanolite is capable of firing up to 10,000 evenly spaced pulses of high-intensity light per second. This pulsing capability is inherent in the device itself and does not require any external pulsing system. This pulse rate is greater than that of pulsed laser systems, and can be used to provide a continuous tracking capability. The Nanolite also has a broader beam, making target acquisition much easier.

The Nanolite is the brightest nonlaser light source yet developed. Its most intense flashes have a brilliance exceeding 30 million candles per square centimeter, produced by passing thousands of amperes through an arc channel a tenth of a millimeter in diameter. However, the duration of these flashes is so short (a few nanoseconds, or billionths of a second) that very little electrode heating and erosion occur, giving the Nanolite a long lifetime. Both the Nanolite and the unique inductance-free coaxial capacitor used to store energy for discharge through the arc-channel were developed by Dr. Fischer.

Interesting enough, the Fischer optical radar fulfills a requirement established a decade ago by the Air Force for an optical radar system. The initial work under the requirement led to increasingly effective capacitors, and rapid capacitor-discharge techniques. These capacitors were subsequently used by Dr. Fischer for ultrahigh-temperature plasma studies, and to power light sources for ultrahigh-speed photography. ★

SIGNIFICANT RESEARCH-SUPPORT EQUIPMENT AT ARL



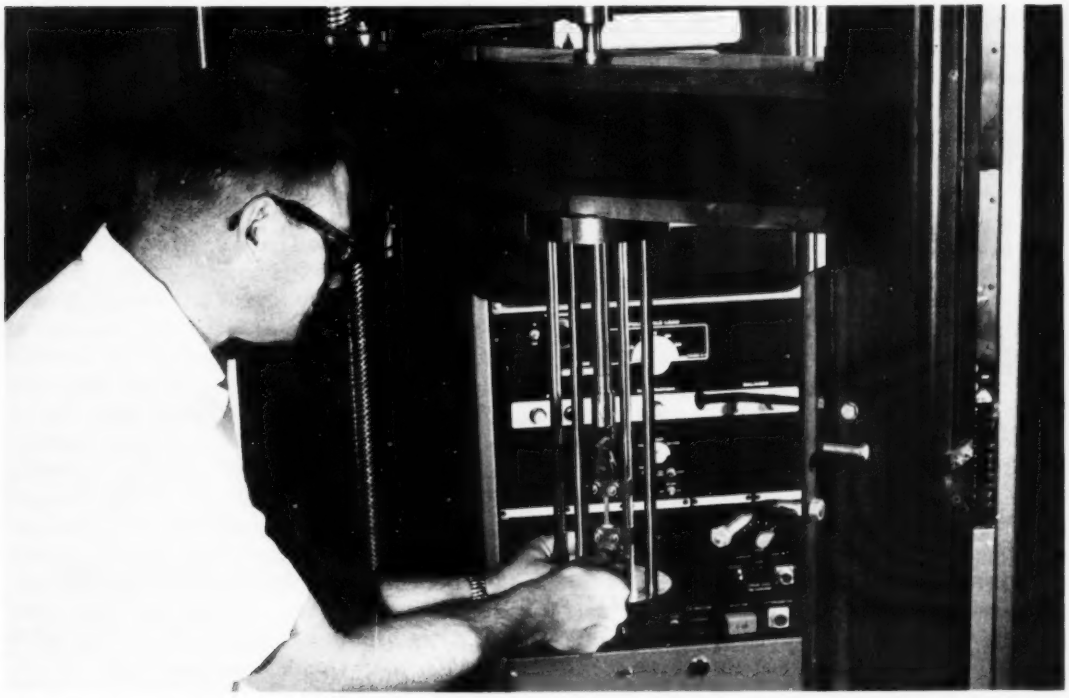
DYNAMIC STABILITY RIG

The dynamic stability characteristics of re-entry vehicles, whether manned or unmanned, are of utmost importance to the Air Force. For example, a manned capsule has marginal dynamic stability characteristics during the re-entry phase.

The hypersonic wind tunnels of ARL are very well suited for the study of the dynamic stability characteristics of various manned and unmanned configurations because they are of the blowdown type with relatively long running times.

A dynamic stability test rig using the small amplitude free-oscillation method was developed by the Hypersonic Research Laboratory for the 20-inch hypersonic wind tunnel. In this method, the model must be suspended on elastic flexures which have extremely low structural damping in order that meaningful differences in the dissipation energy may be obtained for the "wind on" and "wind off" conditions. This characteristic was obtained in the present balance, and several tests were made with a slender cone model at a Mach number of 14 at an extremely low reduced frequency. Results with different flexures were repeatable.

24" reflector telescope used in satellite tracking. ARL's General Physics Research Laboratory is conducting research delineating the shapes and sizes of satellites by their light reflection.



Instron testing machine used by the Metallurgy and Ceramics Research Laboratory, ARL, in the study of flow and fracture characteristics of metals over a wide temperature range.

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